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(56) Documents Cited
EP 0737845 A1 **EP 0634628 A1** **WO 97/35166 A1**
US 5596494 A **US 5557397 A**

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(54) Abstract Title
Environmental data collection system

(57) The invention relates to environmental data containing combined geo-referenced height data and spectrographic data and/or classification data (for example land cover data) derived from spectrographic data, and to a method and system for obtaining such data. The data may be arranged as a file comprising; position (which may be GPS derived), height from which the data is obtained (which may be determined using LIDAR fixed to an aircraft for example), spectrographic data (which may include data obtained from an IR system, video camera or digital camera) and/or classification data (for example vegetation). The invention also relates to uses of such data for environmental analysis.

Fig 1

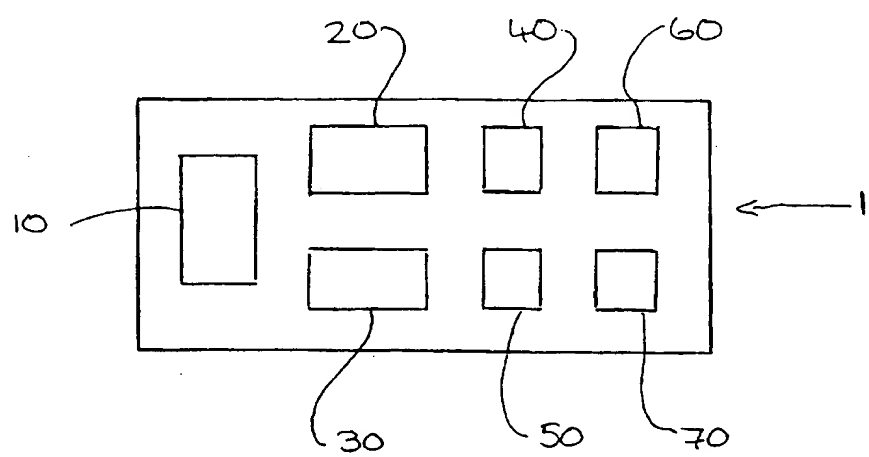

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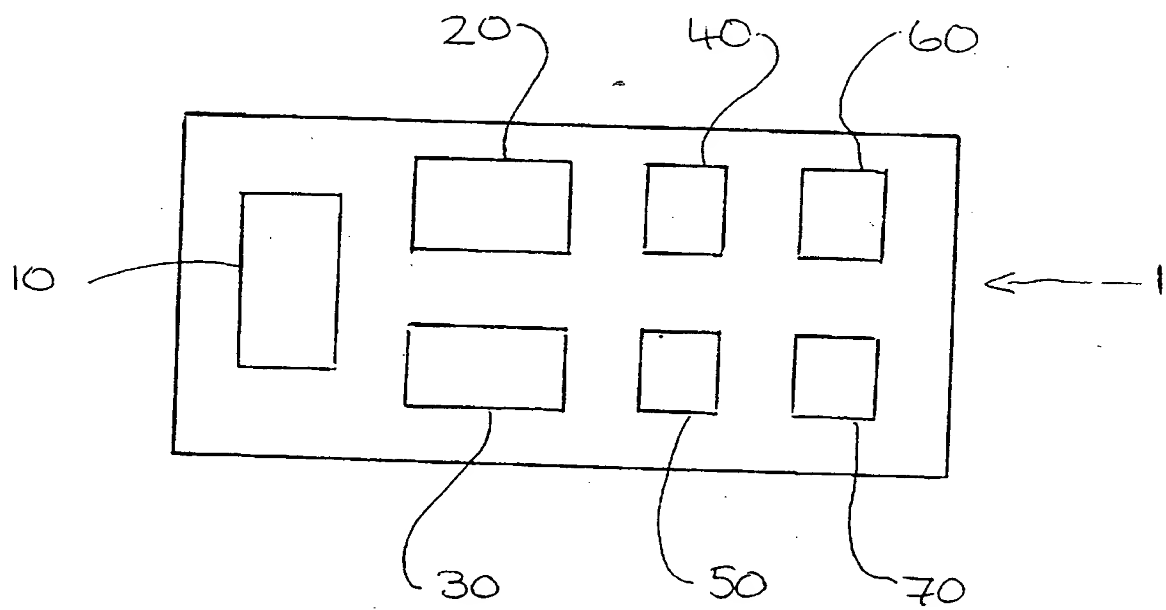
Fig 1



ENVIRONMENTAL DATA, AND METHOD AND SYSTEM FOR OBTAINING ENVIRONMENTAL DATA

The present invention relates to environmental data and to a method and a system for obtaining environmental data.

The term "environmental data" covers a variety of different types of data relating to the environment, for example (but not exclusively) height data and spectrographic data.

Generally such environmental data is collected from the air since this method enables a large area to be covered in as short a time as possible. Previously, such environmental data has been collected using devices carried on satellites but this has proved unsatisfactory owing to the low resolution achieved by such devices and the frequent presence of cloud cover obscuring the area of interest. Airborne systems have also been proposed to overcome the disadvantages of the satellite based systems.

One previously known airborne system is a LIDAR (LIght Detection And Ranging) system for obtaining height information. The LIDAR system is mounted in an aircraft, for example a light aircraft, and is flown over an area for which the height information is required. The LIDAR system is supplied with positional information and records a log of height information and positional information relating to the overflown area.

Another previously known airborne system is a multi-spectral scanning or imaging system, such as a CASI (Compact Airborne Spectrographic Imager) system, for obtaining spectrographic information. The CASI system is mounted in an aircraft, for example a light aircraft, and is flown over an area for which spectrographic information is required. The CASI system is supplied with positional information and records a log of spectrographic information and positional

information relating to the overflown area.

Although the prior art systems can provide useful information, detailed environmental analysis of the environment is not achievable with the prior art systems.

According to one aspect of the invention, there is provided environmental data containing combined geo-referenced height data and spectrographic data and/or data derived from spectrographic data.

Advantageously, the spectrographic data is classified, for example in order to determine the land cover, and the environmental classification data is stored with the height data, either with the spectrographic data or in place of the spectrographic data. Most preferably, the environmental data provided in accordance with the invention comprises combined geo-referenced height data and environmental classification data. In particular the environmental data may comprise a data set or data file comprising positional information, height information and environmental classification information. The data is preferably stored on a pixel by pixel basis, but the classification data advantageously may be stored in connection with a group of pixels. The environmental classification data may contain information relating to the land cover, for example whether a particular area is covered with grass, for example, or maize.

The environmental data is electronically stored.

The environmental data is preferably organised in such a manner so as to be easily searchable. In particular, the environmental data may be arranged so as to be searchable using height or spectrographic or classification or positional parameters, or using a combination of such parameters. This can be achieved by storing height data, spectrographic data and/or data relating to or derived from spectrographic data, such

as classification data, in association with the relevant position data.

According to a second aspect of the invention, there is provided a method of environmental analysis comprising the steps of inputting relevant parameters and searching the environmental data of the invention to find matches.

According to a third aspect of the invention, there is provided apparatus for environmental analysis, comprising:

memory means containing environmental data of the invention;

means for inputting search parameters; and

means for searching the environmental data using search parameters.

In a particularly advantageous embodiment of the invention, the environmental data includes environmental classification data and the parameters used to search the environmental data include environmental classification parameters.

A fourth aspect of the invention relates to the use of the environmental data of the invention for environmental analysis.

According to a fifth aspect of the invention, there is provided a method of obtaining environmental data of an area by combining height data relating to that area and spectrographic data relating to that area to obtain environmental data containing combined geo-referenced height and spectrographic data.

The method of the invention may also include the step of forming classification data from the spectrographic data and forming environmental data including the classification data instead of or in addition to the spectrographic data.

The height data and the spectrographic data may be combined at individual locations or interpolated data

may be used.

The method may also comprise the step of obtaining the height data.

The method may also comprise the step of obtaining the spectrographic data.

However, once obtained, the height data may be combined with spectrographic data measured at a number of different times, for example on a seasonal or on an annual basis, in order to evaluate changes in land cover.

In an advantageous embodiment, the method of the invention is used to combine height information and spectrographic information collected simultaneously.

The method comprises additional processing steps to combine the spectrographic information and the height information.

The method also includes the step of storing the environmental information in a data set or data file, in particular a data set or data array one which is searchable electronically by parameters.

According to a sixth aspect of the invention, there is provided an environmental monitoring system comprising, in combination, a position monitoring device for monitoring the position of the environmental monitoring system, a system for obtaining height data about an area, and a system for obtaining spectrographic data about an area.

The position monitoring device may output position data to the system for obtaining height data and to the system for obtaining spectrographic data, and the system for obtaining height data and the system for obtaining spectrographic data record position information together with the respective information about the environment.

The environmental monitoring system may also include processing means for obtaining environmental

data of an area by combining height data relating to that area and spectrographic data relating to that area to obtain environmental data containing combined geo-referenced height and spectrographic data.

The position monitoring device is preferably a GPS system device.

Preferably the GPS device of the environment monitoring system receives information from a satellite GPS system and correction information from a land based source to determine accurately the position of the system.

The environmental monitoring system may be carried on an aircraft.

The environmental monitoring system may also include one or more of: IR system; camera; digital camera; video.

According to a seventh aspect of the invention, there is provided an aircraft fitted with an environmental monitoring system as claimed above.

The position monitoring device is preferably capable of obtaining the position of the measurement to an accuracy of the order of 1 metre in the x and y directions, and most preferably the position is determined to an accuracy of around 0.5 metres or less.

The system for obtaining height data preferably is capable of measuring height to an accuracy of the order of 0.5 metres, and most preferably the height is measured to an accuracy of around 10-15cm or less.

The height data may be collected from a LIDAR system, for example.

The spectrographic data may be collected from a CASI system, for example.

The environmental analysis carried out in accordance with the invention may relate to one or more of the following: flood risk mapping; coastal zone mapping; assessment of coastal erosion; assessment of

soil erosion; evaluation of vegetation stress; classification of vegetation; assessment of pollution diffusion; evaluation of open cast mines and quarries; evaluation of the use of landfill sites; evaluation of water resources; evaluation of water quality; mapping and evaluation of land cover or changes in land cover; determination of likely environmental effects of proposed course of action or of postulated events. However, the invention is not limited to the above list.

Where the term "height" is used in this specification, it should be taken to refer to both height above and depth below sea level.

For a better understanding of the present invention, and to show how it may be brought into effect, reference will now be made, by way of example, to the accompanying drawing, in which:

Figure 1 shows a block diagram of an environmental monitoring system in accordance with the invention.

An embodiment of the present invention will now be described with reference to the drawings. In the following description reference is made to the CASI system. However, clearly any multi-spectral scanning or imaging system may be used to provide the required spectrographic data.

Figure 1 shows an environmental monitoring system 1 according to the invention. The environmental system 1 is mounted on an aircraft which can be flown over the target area from which the environmental data is to be collected.

The environmental monitoring system 1 in this illustrative embodiment comprises a GPS positioning system 10; a LIDAR system 20; a CASI system 30; an infra-red camera 40; a camera 50; a digital camera 60; and a video camera 70. However, it is not essential that all of these systems are present in the

environment monitoring system 1 of the present invention.

In addition, the environmental monitoring system 1 also includes other sensors to measure, for example, the pitch, yaw and roll of the aircraft. The output of these sensors are used in a known manner to modify the positional information used by the different components of the environment monitoring system 1 in order to ensure that the positional information recorded by the LIDAR system 20 and the CASI system 30 corresponds to the point where the measurements are being made. This aspect is well known and is not therefore considered further.

The GPS system 10 obtains positional information from the GPS satellite positioning system. However, as is well known, the positional information which can be obtained from the GPS system at present is not highly accurate. In fact, the GPS system currently provides an accuracy of the order of 50-100 meters. Clearly, it is important for the position of the aircraft to be known as accurately as possible while measurements are taken by the LIDAR system 20 and CASI system 30.

A preferred method of ensuring that the positional information is as accurate as possible uses a ground-based station to generate a correction signal for correction of the positional information which can be obtained from the satellite. The position of the ground-based station is known accurately, and the correction signal can be obtained by comparing the known position of the ground-based station with the information received by the ground-based station about its position from the satellite. The correction signal can then be sent to the aircraft to correct the information received from the satellite by the aircraft. The positional information supplied by the GPS system 10 to the LIDAR system 20 and the CASI

system 30 is generally accurate within 0.5 metres.

The operation of the LIDAR system 20 will now be explained. While the aircraft is overflown the area of interest, the LIDAR system 20 receives positional information from the GPS system 10 and measures height information of the overflown area. This height information and the corresponding positional information is usually stored in a log.

The LIDAR system 20 measures height information by emitting a light pulse and receiving the reflection of the emitted pulse from the area of interest. The time interval between the time at which the laser pulse is emitted and the time at which the reflected pulse is received is measured, which time corresponds to the difference in height between the point in the area of interest which is being measured and the aircraft, and is stored together with the position of the measurement. The height can be measured to an accuracy of 10-15cm.

The LIDAR system 20 can be used to measure a variety of height features on land and on the sea bed. Clearly, the wavelength of the light used must be chosen to be suitable for the measurements being taken, as is well known to a person skilled in the art.

The operation of the CASI system 30 will now be explained. While the aircraft is overflown the area of interest, the CASI system 30 receives positional information from the GPS system 10 and measures spectrographic information from the overflown area. This spectrographic information and the positional information is usually stored in a log.

The CASI system 30 is able to measure spectrographic information in a total of 288 channels, each covering a small range of wavelengths. In an exemplary embodiment of the invention, the CASI system 30 is configured to measure spectrographic information

on 15 channels, which are chosen depending upon the nature of the overflown area, as is known to a skilled person. Specifically, the CASI system 30 can be used to measure spectrographic features on land and within a body of water, for example a body of sea water, by suitable choice of channels.

In each of the channels in use, the CASI system 30 measures the amount of radiation received from the surface having a wavelength in that band, and records that information for each of the channels.

The CASI system 30 measures spectrographic information for each pixel of a line of 512 pixels oriented perpendicular to the track of the aircraft. The area covered by each pixel is determined by the height from which the measurements are taken, as is well known. For instance, if the aircraft flies at 10000 feet, one pixel of the image represents a ground area of approximately 10x10 metres: if the aircraft flies at 4000 feet, one pixel of the image covers a ground area of approximately 4x4 metres. The CASI system 30 records for each pixel radiation data in the selected channels from the respective target area.

The data logs obtained from the LIDAR system 20 and from the CASI system 30, containing the GPS data and the respective measured data, are then subjected to a local transformation to convert the GPS positional data points into map-based (e.g. Ordinance Survey) positional data points.

Further, a digital terrain model (or digital elevation model) is used to interpolate between the specific measured data points of the LIDAR data in order to obtain continuous height data over the area of interest.

The LIDAR data obtained from the digital terrain model and the CASI data are overlaid using image processing techniques to produce the environmental data

of the invention. This can be carried out using a geographic information system (GIS).

In one method of producing the environmental data of the invention, the geo-referenced LIDAR and CASI data corresponding to the same ground area are viewed simultaneously using imaging software. In general, features in the two data sets in the ground area under study, such as trees, buildings or roads, for example, will not be in exactly the same positions and so these features are matched to each other. This can be achieved manually by an operator, but it is envisaged that the data sets are matched automatically by image processing software.

Once key features in the data sets have been matched, the two images can be warped together using image processing software to form a single image containing all the information from the two original images. The data sets corresponding to the matched images are also combined to form environmental data in accordance with the invention.

However, if the LIDAR data and the CASI data are measured simultaneously, the two data sets will share the same geo-referencing information and can be combined automatically.

Clearly, the data sets may be combined together without any visual representation of the data, and the method set out above is merely an exemplary method of forming the environmental data of the invention.

The environmental data in accordance with the invention described above consists of combined geo referenced height data and spectrographic data. The data is generally arranged such that it can easily be searched using position, height or spectrographic parameters or a combination of such parameters. Preferably, it is arranged so that, for each area of interest, for example each pixel derived from the

pixels of the CASI data, the positional information indicating that area is stored, for example in a header, together with the LIDAR data for that area and the spectrographic data for each of the CASI channels originally used in the measurement for that area. In this way, the environmental data of the present invention comprises combined height data, as obtained by the LIDAR system, and spectrographic data, as obtained by the CASI system and therefore represents complete environmental information about a particular area. The environmental data is stored so as to be easily searchable.

In a most advantageous aspect of the invention the spectrographic data of an area is analysed in order to obtain environmental classification information relating to that area. This might be achieved by detailed analysis by an operator of the spectrographic information on a pixel by pixel basis or on a number of pixels having similar spectrographic signatures, or profiles, grouped together. Alternatively, the environmental classification might be carried out automatically using software to search through the spectrographic information. For example, a spectrographic profile associated with "grass" "maize" or "tarmac", could be provided to the classification software and if the spectrographic information stored for a particular area matches the spectrographic profile for a known profile, the classification software can classify that area. Information relating to the classification can be added to the data file for that area, or could replace the spectrographic data entirely.

The data obtained using the method and system of the invention can be used for a wide variety of environmental uses. In particular, but not exhaustively, the environmental uses for which the data

of the invention may be used include: flood risk mapping; coastal zone mapping; assessment of coastal erosion; assessment of soil erosion; evaluation of vegetation stress; classification of vegetation; assessment of pollution diffusion; evaluation of open cast mines and quarries; evaluation of the use of landfill sites; evaluation of water resources; evaluation of water quality; mapping and evaluation of land cover or change in land cover; evaluation of contaminated land; and the determination of likely environmental effects of a proposed course of action or of postulated events.

For instance, the environmental data of the present invention may be used to determine the area of agricultural land lying below an elevation of 5 feet which would be flooded by a rise in sea levels.

Clearly, the present invention provides extremely useful environmental data and a method and system for obtaining such data.

CLAIMS

1. A method of obtaining environmental data of an area by combining height data relating to that area and spectrographic data relating to that area or classification data derived from the spectrographic data to obtain environmental data.

2. The method as claimed in claim 1 further including the step of forming classification data from the spectrographic data and forming environmental data including the classification data instead of or in addition to the spectrographic data.

3. The method as claimed in claim 1 or 2, wherein height data is combined with spectrographic data and/or environmental classification data which has been obtained on more than one occasion to form the environmental data.

4. Environmental data containing combined geo-referenced height data and spectrographic data and/or data derived from spectrographic data.

5. Environmental data as claimed in claim 4, wherein the spectrographic data is classified, and the resulting environmental classification data is stored with the height data, either with the spectrographic data or in place of the spectrographic data.

6. Environmental data as claimed in claim 5, wherein the spectrographic data is classified to determine land cover.

7. Environmental data as claimed in any one of claims 4-6 formed as a data file comprising: positional data; height data; spectrographic data and/or environmental classification data.

8. Environmental data as claimed in any one of claims 4-7, wherein the environmental data includes spectrographic data and/or environmental classification data measured on at least two different occasions.

9. Environmental data as claimed in any one of

claims 4-8 wherein the environmental data is organised so as to be easily searchable.

10. Environmental data as claimed in claim 9 wherein the environmental data is arranged so as to be searchable using height or spectrographic or classification or positional parameters, or using a combination of such parameters.

11. An apparatus for environmental analysis, comprising:

memory means containing environmental data as claimed in one of claims 9 or 10;

means for inputting search parameters; and

means for searching the environmental data using search parameters.

12. An environmental monitoring system comprising, in combination, a position monitoring device for monitoring the position of the environmental monitoring system, a system for obtaining height data about an area, and a system for obtaining spectrographic data about an area.

13. The environmental monitoring system as claimed in claim 12 also including processing means for obtaining environmental data of an area by combining height data relating to that area and spectrographic data relating to that area to obtain environmental data containing combined geo-referenced height- and spectrographic data.

14. An aircraft fitted with an environmental monitoring system as claimed in claim 12 or 13.

15. Use of the environmental data obtained by the method of one of claims 1-3 or as claimed in any one of claims 4-10 for environmental analysis comprising the steps of inputting relevant parameters and searching the environmental data of the invention to find matches.

16. Use of environmental data for environmental

analysis, as claimed in claim 16, wherein environmental analysis relates to one or more of the following: flood risk mapping; coastal zone mapping; assessment of coastal erosion; assessment of soil erosion; evaluation of vegetation stress; classification of vegetation; assessment of pollution diffusion; evaluation of open cast mines and quarries; evaluation of the use of landfill sites; evaluation of water resources; evaluation of water quality; mapping and evaluation of land cover or changes in land cover; determination of likely environmental effects of proposed course of action or of postulated events.

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Claims searched: All
Examiner: C R Brain
Date of search: 26 August 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G1A (ABAX, ABGX); H4D (DAA, DAB, DLAA, DLAB)

Int Cl (Ed.6): G01C 11/00, 11/02; G01S 5/14

Other: Online: WPI, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP 0737845 A1	(CORE)	
X	EP 0634628 A1	(Deutsche Aerospace) See particularly column 4, lines 36-40 and lines 55-58.	1, 4, 12, 13, 14.
X	WO 97/35166 A1	(TASC) See particularly page 5, lines 18-20 and page 12, lines 23-26.	1, 4, 12, 13, 14.
A	US 5596494	(Kuo)	
A	US 5557397	(Hyde et al)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		